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James Clerk Maxwell's Scottish chair

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This account of Maxwell as professor of natural philosophy at Marischal College, Aberdeen, fills in many details that have been left out of Maxwell's biographies. It discusses the degree programme that Maxwell taught on, the nature of his colleagues, the type of student he had in his classes and the range of activities involved in his teaching. Evidence is cited that Maxwell was an enthusiastic and effective teacher, contrary to the often repeated but thinly supported view to the contrary. Following a brief summary of Maxwell's research interests while at Aberdeen, the myth that Maxwell was sacked from the University of Aberdeen is exploded and the detail of why he moved on is spelt out.

Keywords: James Clerk Maxwell; biography; Marischal College; Aberdeen; natural philosophy; undergraduate teaching

1. Introduction

James Clerk Maxwell spent about a quarter of his professorial career at Marischal College, Aberdeen—four academic years. It was the only Scottish chair that he held. It was a seminal time of his life, when he made the change from bright young man to the most perceptive physicist alive. Yet there have been only two papers devoted to Maxwell at Aberdeen. The first was written by a former Marischal College pupil[1] of Maxwell in an article aimed at alumni and published 60 years after Maxwell arrived at Marischal College. The second (Jones 1973) was written approximately 35 years ago by a successor in Maxwell's chair, or what became of it. Both drew heavily on readily available sources. Jones (1980) published a more general article on Maxwell on the centenary of his death.

Maxwell's scientific achievements at Aberdeen were significant and can be followed in a number of biographies (Campbell & Garnett 1882; Everitt 1974; Tolstoy 1981; Goldman 1983), in his collected papers (Niven 1890) and in his collected correspondence (Harman 1990*a*). The definitive biography based on extensive personal knowledge and source material now lost is that of Lewis Campbell and William Garnett. In this account I would like to cover subjects not

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[1] A distant reminiscence by a former student of Maxwell at Aberdeen is recorded by Walker (1916) but is disappointingly dependent on Campbell and Garnett's biography. Robert Walker became assistant to the professor of mathematics at the University of Aberdeen from 1868 to 1870, university librarian from 1877 to 1893 and was secretary to the University Court for 30 years.

One contribution of 20 to a Theme Issue 'James Clerk Maxwell 150 years on'.

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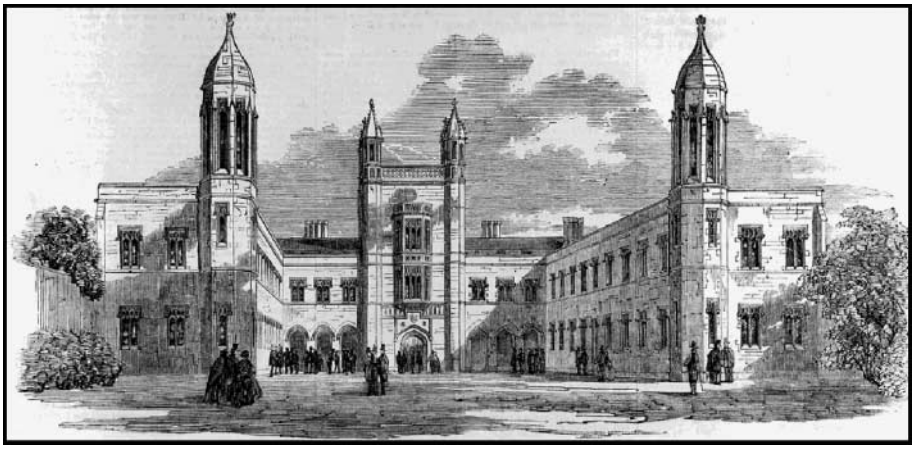

Figure 1. Marischal College sketched in 1859 at the opening of the meeting of the British Association for the Advancement of Science in Aberdeen. Drawn for the *London Illustrated News* but reproduced subsequently as a separate print.

treated in accounts of Maxwell's life, painting a picture of Marischal College in Maxwell's time that shows the professors who taught there, the students who came to Maxwell's classes and Maxwell's own teaching. There is only the briefest mention of the scientific work that occupied his thoughts over the four sessions from 1856 to 1860 that he held the chair of natural philosophy. Finally I will elaborate on why he moved on.

In 1856, Marischal College was already 253 years old, a university in its own right. Its premises had been twice replaced. Looking at figure 1, one has to imagine the sparkling silver-grey granite of an almost new Marischal College building, the academic home of the newly appointed 25-year-old professor of natural philosophy, James Clerk Maxwell.

2. Marischal College

In 1856, the business of the college was its general MA degree, its substantial medical school and its small postgraduate schools in law and divinity. Approximately 200 students were enrolled at one time in the 4 years of the MA course (table 1[2]). There were subject entrance exams for the regular students (called 'gowned' students) but courses were open to private students as well.[3] Private students of natural philosophy were exempted from any entrance examination but were required to have a 'competent knowledge of mathematics'.

[2] A mass of factual information on Marischal College was accumulated by two Royal Commissions in the nineteenth century, investigating the possibility of a merger with neighbouring King's College. The details quoted in this paper are not individually referenced throughout. See the *General Report of the Commissioners under the Universities (Scotland) Act 1858* (Edinburgh, HMSO 1863). A useful summary of the arts teaching was published by the university librarian and former assistant to the professor of natural philosophy, Anderson (1892).

[3] Both for information and to attract private students, the courses at Marischal College were advertised in the press. For example, *The Aberdeen Journal*, 22nd October 1856 for the first appearance of Prof. Maxwell's name in the advertisements.

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Table 1. Total number of MA students in Marischal College in Maxwell's first year (1856–1857). (The degree programme lasted for 4 years. Column 1 refers to the year of study of the students.)

year	total	private
first	72	1
second	68	19
third	39	10
fourth	27	1
total	206	31

Table 2. The outline syllabus at Marischal College.

year	15 hours per week (main subject)	6 hours per week (secondary subject)	3 hours per week (optional)
first	Greek and Latin		
second	civil and natural history	mathematics	Greek and Latin
third	natural philosophy	mathematics	Greek or chemistry
fourth	moral philosophy and logic	evidences of Christianity (not 6 hours per week)	chemistry or, later, natural philosophy; other special options

Maxwell himself knew the Scottish system very well, for he had been a private student in the University of Edinburgh for 3 years in his late teens.

The college shared in the Scottish reputation for providing good and accessible education. Its purpose, as one graduate of the first half of the nineteenth century put it (quoted by Ogilvie 1876), was to train 'the greatest number possible of talented and industrious youths of the province to accurate classical and scientific knowledge, and to fit them for engaging successfully in any line of life'. Educating high-flying scholars was not an explicit aim. It is perhaps significant that when Maxwell applied for the chair of natural philosophy he faced competition from P. G. Tait and William Swan, arguably stronger men than he faced at King's College in London 4 years later. Tait and Swan would end up in the equivalent chairs in Edinburgh and St Andrews universities, respectively.

The MA was available only to enrolled students who had successfully completed their 4-year study of the traditional subjects of Latin, Greek, natural history, mathematics, natural philosophy, moral philosophy, logic and evidences of Christianity. Table 2 outlines the degree programme syllabus. In addition, students had to pay a significant fee to graduate.[4] Many took the subjects but did not pay to collect their degree. There were also optional classes in chemistry, agriculture, Roman history, rhetoric and English literature and in advanced Greek, Latin, natural philosophy (introduced by Maxwell) and mathematics. In Maxwell's time, the degree was known by its Latin initials of artium magister (AM).

[4] Graduation cost £5, comparable to the annual class fees and equivalent to approximately £1000 in year 2000 currency. The reluctance of some able students to collect their degrees was understandable.

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Table 3. Number of students in Maxwell's principal (Tertian) class.

	1856–1857	1857–1858	1858–1859	1859–1860
gowned	39	27	40	41
private	10	10	9	13

Table 4. Maxwell's professorial income in his first year (1856–1857). (Sums are quoted in pounds, shillings and pence.)

college funds (from interest, endowments, rents)	£180 10 0
parliamentary grant	£43 16 0
class fees	£157 4 0
total	£382 4 0

Maxwell taught the major component of the degree programme in a student's third year, or Tertian year as it was known. Typically, he had approximately 50 students in this class, as shown in table 3. He also had other teaching, as will be discussed later.

The money was not particularly good, as can be seen in table 4. Maxwell's pre-tax professorial income in his first year was just under £400, a little over £1 per day. In these circumstances, there was a significant incentive to establish a reputation for good teaching that would attract more private students, at 3 guineas per annum per student. Gowned students paid only 2 guineas for their natural philosophy course.

(*a*) *The professors in 1856*

There are times in the life of every college when it is abuzz with activity and innovation. The experienced staff who have made their reputation and the younger staff with new ideas keep the college name in the public eye. Such was Marischal College in the 1780s. Such, though, was not Marischal College in 1856, at least when it came to their arts degree. The college had a notable record for appointing youthful professors, three outstanding choices in the eighteenth century being made at the age of 19. Marischal College staff, when Maxwell arrived at the age of 25, were far from youthful. They had an average age of 54. They can be seen in figure 2.

The staff who taught the AM students were almost all Scots; two were former graduates of the college. They can be divided into two groups: the divines and those with scientific training. They were headed by the divines.

(i) *On the humanities and divinity side*

Principal Dr Daniel Dewar, professor of Church history, author of *sundry theological works*, as the college records put it, aged approximately 60. His appointment to the principalship in 1832 was notable as having 'the unanimous disapproval of the College' (Anderson 1898). Dewar and his family took very kindly to Maxwell but, hardly surprisingly, Dewar was not a favourite in the college and his lectures on Christian evidences delivered to final year students did not hold the attention of his class.

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Figure 2. The roll of professors who gave the courses that were a compulsory part of the Marischal College MA programme.

Robert James Brown, aged 64, professor of Greek since 1827, former minister of the church and son of a previous college principal.[5] Students had an affection for Brown, who has been described as a good and industrious scholar.

William Pirie, aged 52, professor of divinity; another former minister of the church, a future moderator of the General Assembly of the Church of Scotland and future principal of the University of Aberdeen. He was described by Maxwell as 'the greatest wag in College'.

Robert Maclure, aged 50, professor of humanity; former Edinburgh school-teacher and author of an undergraduate work on Latin. Maclure was, I believe,

[5] The Fasti (Anderson 1898) pp. 3–77 contain short biographical notes on all officers of Marischal College, from the foundation.

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the only member of the Marischal College staff that Maxwell knew before coming to Aberdeen, having been a schoolteacher in Maxwell's old school, the Edinburgh Academy.

William Martin, aged 40, professor of moral philosophy, another licentiate of the Church of Scotland, and author of several religious works. Martin's knowledge did not appear to be up to the job. 'His absorbing passion was to save the souls of his students without having a very clear idea of what was meant by salvation and what was meant by souls' as one reminiscence put it (Donaldson 1906). Martin has been remembered as 'a perpetual entertainment and delight to students' in Maxwell's words, not on account of his effective teaching but because he was constantly the butt of student humour, both inside and outside his class. However, the twist in the tail is given in an account by a former student who became the principal of St Andrews University. He wrote about Martin in his undergraduate days at Marischal College 'The professor was continually suggesting new lines of thought and raising doubts within us of the soundness of his own opinions. In this way the defects were a strong stimulus to thought, and the members of the class took a profound interest in the whole subject' (Donaldson 1906). Martin's educational technique works as an exception but would have created a shambles had it been a common practice. Martin and Maxwell went on daily walks together for some time, an unlikely pair if one were to judge only by the reminiscences above.

(ii) *On the scientific side*

John Cruickshank, aged 69, professor of mathematics; in spite of his age an able teacher, administrator and past reformer. A biography of Cruickshank has been given by Ogilvie (1876). It was Cruickshank who many years earlier had introduced an entrance exam to each year of study at Marischal College and 6 days of final degree exams to give the Marischal degree real credibility. Amazingly enough, these practices were not adopted in other Scottish universities for some 50 years, until the Commission of 1889 put them into their ordinances. Cruickshank had been taking classes since 1817.

James Nicol, aged 46, professor of natural history and one of the real stars of Marischal College; more widely travelled than most others at Aberdeen, having studied in Berlin and Bonn, and having formerly been professor of geology & mineralogy in Cork (Anderson 1906). Nicol's perceptive work on the geology of the west of Scotland was poorly appreciated in his time and only recognized to be essentially correct later in the century. For this work, at least, he is still remembered.

Also on the scientific side was *Thomas Clark*, not included in the picture because his classes were optional for Marischal College students, professor of chemistry; a man of great energy and force of character who was described rather sadly by Thomas Graham in the words 'Clark narrowly escaped being a great man' (quoted by Finlay 1935; see also Chalmers 1980). His name is remembered to this day by analytical chemists, not merely Aberdonians, as the first to invent a test for water hardness that was used until only a few decades ago, and to patent a feasible method of bulk water softening. Unfortunately, since 1844, Clark had annually presented a certificate of ill health (severe and persistent migraine) that allowed his lectures to be given by a substitute. The substitute in Maxwell's day was James S. Brazier, 'a favourite with old and young' in

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Maxwell's words; Brazier was then lecturer in agriculture but later became professor of chemistry at Aberdeen after Maxwell left.

These were Maxwell's colleagues, responsible with him for the 4-year MA course. A few were pretty good, but remembering that Maxwell as an undergraduate at Edinburgh had been taught by Philip Kelland in mathematics, James D. Forbes in natural philosophy and William Hamilton in logic, Marischal College could not provide the equivalent intellectual life (few places could!). In Aberdeen, Maxwell had the additional acquaintance of academics from the second university, King's College. Among the professoriate, there was the able Frederick Fuller, professor of mathematics, a man highly rated as a teacher by the King's College students. Fuller was an Aberdonian, born in the shadow of King's College itself, who had been Maxwell's mathematical tutor at Peterhouse when Maxwell first went to Cambridge, and one of those who wrote a testimonial for Maxwell to support his application for the Marischal chair.

In the ordinary course of events, half of the Marischal College staff would probably have been replaced in the 1860s, for in that decade five would have departed or died and Maxwell could have found himself with young and innovative colleagues. These were not ordinary times. When Maxwell arrived, there was already in full swing a heated and prolonged debate on a merger with the neighbouring 'University and King's College'. That debate, which dominated the university life for the whole of Maxwell's tenure, became a debate for the survival of the two-and-a-half-century-old Marischal College. Ultimately, the college lost its independent status and Maxwell was to be the last professor of natural philosophy at Marischal; a glorious finale for the college, at least in natural philosophy.

Brown, Nicol, Martin and Maxwell himself were regents, posts that went back to the foundation of the college itself in 1593. Each regent had the principal class in one of the undergraduate years. When Maxwell came, he was merely a young replacement for the previous Prof. David Gray, a competent teacher who had tragically died only a decade into his career. The first business meeting of the Senate at which Maxwell featured among the *sederunt* simply re-elected the sacrist and the porter. It is not surprising that he had nothing to say on that occasion. It is slightly more surprising that he seems to have had virtually nothing to say at the Senate in the ensuing three-and-a-half years.[6] He never raised a motion in any of the ninety Senate meetings he could have attended, nor had his opinion recorded on any substantial matter. In fact, he missed more than half the Senate because he was only in attendance at college from the end of October until early April each year.

In spite of these slightly unpromising circumstances, I would argue that Marischal College was the right place at the right time for Maxwell. The college was not unfriendly, nor overbearing. After a short while at college, he wrote to P. G. Tait (then at Belfast) 'the work here is much more to my taste than lecturing the second lot of men at Trinity'.[7] Near the end of his first year, he wrote to his old teacher J. D. Forbes: 'now I am quite sure that I am better here than at Cambridge' (Harman 1990*b*). After 2 years of experience: 'This College

[6] The Senate minutes of Marischal College 1845–1860 are recorded in Aberdeen University Library Ms M45.

[7] Harman (1990*a*–*i*) reproduces extant correspondence of Maxwell. Letter to P. G. Tait, 3 December 1856. See p. 480. Many letters, although not this one, are also quoted in Campbell & Garnett (1882).

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work is what I and my father looked forward to for long and I find that we were both right, that it was the thing for me to do. And with respect to the particular College I think we have more discipline and more liberty and therefore more power of useful work than anywhere else' (Harman 1990*c*).

The need for both 'discipline' and 'liberty' by Maxwell is absolutely characteristic of him. Some people thrive by monastic concentration on a chosen speciality. Maxwell needed a balance of opposing experiences to keep himself fresh: he needed the contrast of the city life of Aberdeen and the country life of his estate of Glenlair in Southwest Scotland, the contrast of college matters and estate business, of teaching and research, of experiment and mathematics, of the inanimate objects of physics and of people, of worldly events and spiritual reflection. Marischal College, with its freedom to teach the course he saw fit, within limits, the freedom from formal collegiate life, the freedom to spend half the year on his estate (which he had just inherited upon the death of his father), to attend British Association meetings or simply visit friends and relatives, was ideal for Maxwell in many respects. It is in terms of this need for a *balance* of life's rich offerings that his marriage to Katherine Mary Dewar, the second daughter of the unpopular Principal Dewar, can be viewed. Katherine nourished the spiritual side of Maxwell which, for reasons of the times, is not well documented and does not appear much in the Maxwell biographies.

3. Maxwell's undergraduates

Maxwell's average student was aged 18 years 9 months on entry to his lectures. Figure 3 shows a Marischal College student of 1859, posing in his new crimson toga with its characteristic velvet collar. The toga was an item of everyday use (hence the name 'gowned students'), its blind sleeves being ideal receptacles for secreting heavy objects that could turn the sleeves into weapons of assault. The King's College students at Aberdeen's second university about a mile down the road wore an almost sleeveless red toga, putting them at a disadvantage in impromptu meetings.

The college engendered a considerable spirit of comradeship and affection among its students. Many places do. Thanks to the efforts of graduates to keep in touch with each other and with the college, we know much more about many of Maxwell's students than simply their names.[8] Indeed, Maxwell's first class published a book that gave biographical details of each member, as remitted to one of their number (Chalmers 1879). This book ran to three editions, being updated over the decades as careers matured. Sources such as this and the published college records (Anderson 1898) that have notes added by an indefatigable former librarian, P. J. Anderson, enable one to write two- or three-line biographies of some 90% of the 189 students that Maxwell taught. Maxwell scholars need have no fears if they can answer such questions as 'which prolific author of juvenile tales of romance and adventure was taught natural philosophy by James Clerk Maxwell?' (William Gordon Stables) or 'which Scottish student of JCM became a professor at University College London?' (G. C. Robertson).

[8] The class rolls of Marischal College from 1605 to 1859 have been published by Anderson (1898). Data for table 1, and some subsequent information on Maxwell's students, come from this volume.

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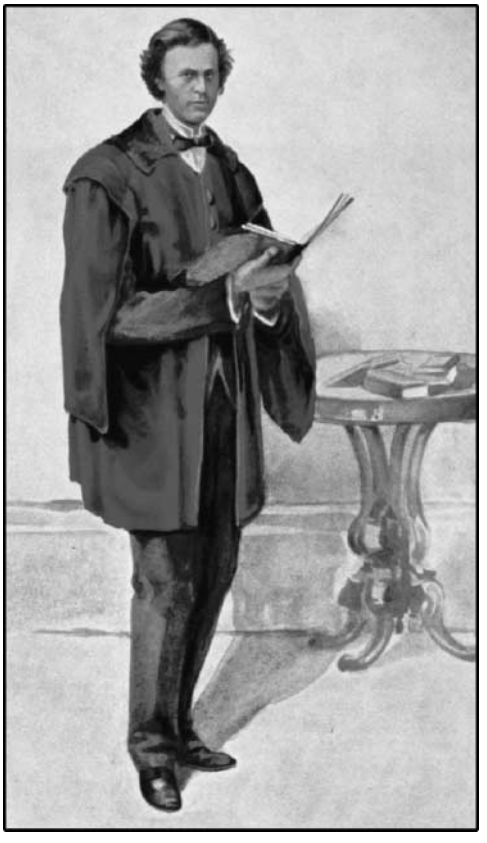

Figure 3. A Marischal College student of 1859 modelling the toga worn daily that distinguished enrolled 'gowned students' from private students.

I have summarized the biographical information on Maxwell's students in tables 5–8, to answer four questions.

Where did Maxwell's students come from? Table 5 shows that they were mainly local lads. Almost half of them were born in Aberdeen; many of the rest in the northeast of Scotland. A significant number of those born 'elsewhere' had in fact lived in or around Aberdeen, their place of birth being an accident of their father's occupation.

What background had the students; in particular what was the occupation of their fathers? Table 6 shows that the greatest proportion of students were sons of tradesmen: masons; wrights; millers; saddlers; shoemakers; merchants; booksellers; smiths; ironmongers; druggists; and so on. Aberdeen rightly has a name for educating large numbers of farmers' sons. A significant number of these did go to Marischal College but the majority, by tradition, went to King's College. One feature of life that comes through assorted reminiscences is that students at the time found the atmosphere in the college was immensely democratic. The son of a ploughman was on equal terms with the son of a professor—the only distinction recognized being any in their learning and ability, and the ploughman's son could well have the better of it. Maxwell would have appreciated such equality.

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Table 5. The places of origin of Maxwell's Marischal College students.

born in	number
Aberdeen	75
Aberdeenshire	66
neighbouring shires	20
elsewhere	28
total	189

Table 6. Maxwell's Marischal College students' backgrounds.

father's employment	number
farmer	30
professional	55
trade	81
white-collar	14
others	9
total	189

Table 7. Careers followed by Maxwell's Marischal College students.

careers	number
medicine	37
church	29
teaching	25
law	28
engineering	11
white-collar	16
trade	14
others	10
unknown	18
total	188

Table 8. Career locations of Maxwell's Marischal College students.

careers in	numbers
Aberdeen	40
rest of Scotland	37
England	26
abroad	47
army	8
unknown	30
total	188

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What careers did the students take up in later life? Table 7 shows indicative statistics but they are less precise than the previous figures. Men did not always stay in the same career: aspiring ministers of the church may have taken to schoolmastering for quite some time before securing a charge; illness or injury may have forced a new life. That said, over two-thirds entered one profession or another, in medicine, religion, teaching or the law. The trades that supplied the bulk of the students received little direct return on their investment. A small number of students became engineers, notably civil engineers for railway companies abroad, or military engineers. The table includes one fewer student than the earlier tables since one student died before graduating.

Only a single student became a recognized scientist—David Gill, one of the leading observational astronomers of the century, a man of great ability and good sense. Gill, a private student in Maxwell's last year, left some reminiscences of his Marischal College days (Gill 1913). Another in that year was Robert Walker, who became assistant to the professor of mathematics at King's College and then University of Aberdeen librarian. Also in that year was George Reith, son of a railway manager, who went on to become a free church minister and father of John Reith, later Lord Reith, who moulded the shape of the BBC in its formative years. It was Prof. R. V. Jones who pointed out the significance of the class certificate of George Reith, signed by Maxwell, linking the predictor of radio waves to the man who shaped their public service exploitation. Jones printed a facsimile of the certificate, which used to hang in Lord Reith's BBC office (Jones 1973).

Some of the best Scottish students went to Cambridge after their Scottish education. Maxwell, P. G. Tait and William Thomson (later Lord Kelvin) all did this. Several Aberdeen students who had been pupils of Prof. David Thomson, Maxwell's contemporary at King's College (Aberdeen), became senior wranglers but none of Maxwell's students emulated them. He did, though, teach at Marischal College for only 4 years. Thomson taught for 35 years.

Finally, *where did Maxwell's students follow their careers?* Table 8 gives the briefest summary. Maxwell's students began life mainly in northeast Scotland but after graduating many went abroad. Scotsmen did not earn their reputation for pervading the professions all over the British Empire for no reason. If the more detailed records kept by Maxwell's first class are representative, many paid for this reputation by early death from disease or injury.

4. Maxwell's undergraduate teaching

Maxwell had a pretty free hand in constructing his undergraduate course; he could choose his own syllabus and his own recommended textbooks. There were no external examiners, and no quality assurance schemes—not that he would have feared either. He inherited a common level of preparation of his students, private ones excepted, who had already received lectures in natural history and elementary mathematics but no previous natural philosophy. He also inherited a very large amount of demonstration equipment, some of it made to a high standard over 50 years previously by a predecessor, Prof. Copland (Reid 1990). He had his own lecture theatre, one of 16 in the college, with a private room attached.

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A former student of Marischal College of a decade or so earlier described the natural philosophy course as he found it: 'a good popular course—very exhaustive, considering the state of knowledge of the time; every leading division of Natural Philosophy was dwelt upon in tolerable minuteness. Dr Copland's apparatus gave almost a superfluity of illustrations in every branch. The weak side of the teaching was no doubt the mathematical part' (Donaldson 1906). Maxwell's course differed from this in almost all important respects: it was selective and not wide ranging; it contained only a *modest* number of lecture demonstrations; it *was* quite strong on the mathematical side.

Maxwell's inaugural lecture at Aberdeen outlining his philosophy of knowledge was summarized in the press at the time and more recently has been printed (Aberdeen Journal 1856; Jones 1973; Harman 1990*d*). One set of student notes taken at Maxwell's final year of Marischal College lectures has come to light (Davidson 1860). The notes now reside at Cambridge along with a set of questions Maxwell asked his class. They were taken by Alexander Davidson, a man who continued his father's paper-making business on the River Don that flows through Aberdeenshire and whose mill survived into this century under the family name but closed in 2005. Davidson was awarded a second-class merit by Maxwell at the end of the course. I found it a very moving experience to read Davidson's notes. I know the Marischal College building quite well, having been for 3 years in the last class that was taught natural philosophy there as a student of the University of Aberdeen, in its old-fashioned lecture theatres with their tiered wooden seating and wood-panelled walls. I have looked at Maxwell's portrait often enough that it was not difficult to imagine myself as I read the notes sitting in Maxwell's class listening to the young man talking, a figure of total concentration on his subject and complete clarity of explanation.

As one would expect, Maxwell liked to set out the principles that underlay specific applications. Thus, while talking about screws, Maxwell remarked (Davidson 1860) 'there are only three kinds of lines that have the property that any bit of it is the same as any other bit of it, namely straight lines, circles and the helix or corkscrew. Hence all parts of machinery that slide or slip upon one another to have this property must be composed either of straight lines, as in a plane, or circular lines as in axles slipping in bushes, or spiral or corkscrew lines'. Take another example, on pulley systems. When describing pulleys, figure 4 illustrates that Maxwell not only explained how different arrangements can be threaded, as his predecessors did, but also took care to explain the principles involved so that arbitrary pulley systems, such as the one drawn here, could be analysed.

His students at times were given materials that today we would reserve in the first year of a Scottish degree for the committed physical scientists. For example, we find Maxwell analysing the statics of a rod on a smooth floor leaning against a smooth wall and being kept from falling by a fixed pin. If the pin is moved up the rod, there comes a distance when it fails to keep the rod from sliding. How far up is this distance and what forces are then exerted on the floor and wall? Today's class of first-year general science students taking a supplementary physics course would make little of this sort of thing. Maxwell was educating future lawyers, churchmen, civil servants, surgeons, merchants and a much broader spectrum than today's science students, men who had done no previous physics. Scottish students were expected to learn a new subject fast. They were also expected to have stamina, too. In figure 5, after at

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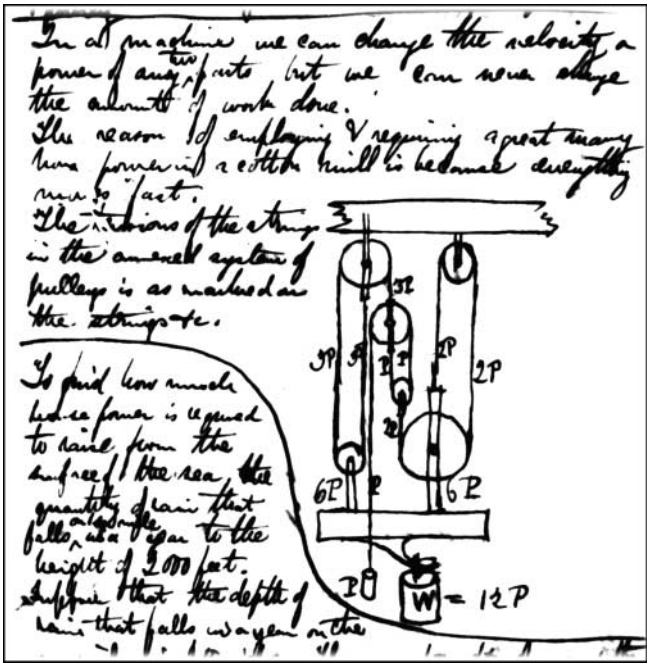

Figure 4. A complex pulley system analysed in Maxwell's natural philosophy course. Davidson's notes are reproduced with permission from Syndics of the Cambridge University Library.

least 120 hours of lectures (each numbered lecture in the notes occupied 2 hours), we find them battling with the algebra of collisions: elastic; inelastic; and partially elastic.

Maxwell also used lecture demonstrations, a number of his own making as well as those from Copland's stock, such as are illustrated in figure 6. Surely it is the professor himself illustrated in the demonstration in figure 7, visible evidence that Maxwell did indeed have his lengthy beard while at Marischal College. David Gill describes in a reminiscence (Gill 1913) how Maxwell would stay behind after the formal lecture for hours, discussing the topic of the day and showing interested students apparatus he had contrived and was experimenting with.

Maxwell came around to recommending to his students the manuals of the Irish authors Galbraith and Haughton,[9] which look simpler than the lecture notes. It is worth recalling that in addition to the huge range of research papers Maxwell published in his lifetime, he also wrote in later years a 'Manual of elementary science' (Maxwell 1876) very much in the style of the Galbraith and Haughton series. The 1920 version slightly edited by Joseph Lamor is still in print. Moreover, in the 1870s, he also published a textbook on heat (Maxwell 1871), which again was popular and, like his *Matter and motion*, is still available as a reprint and in electronic form on the Web.

[9] J. A. Galbraith and S. Haughton produced a monograph series available in the 1850s including: 'Manual of mechanics'; 'Manual of hydrostatics'; 'Manual of optics'; 'Manual of astronomy' (Longman, London). Other manuals covered mathematical topics.

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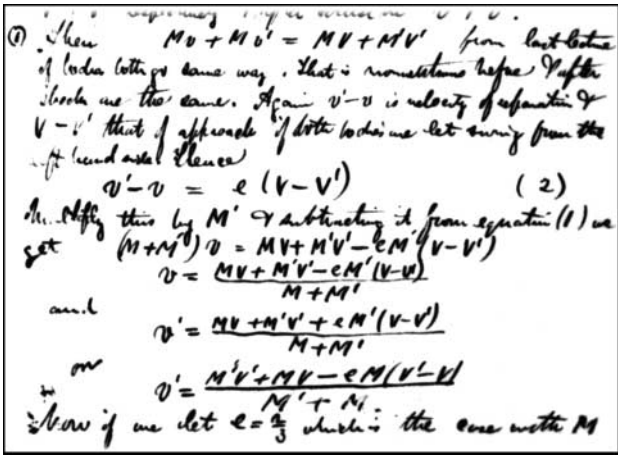

Figure 5. Maxwell's tackling of the algebra of collisions from the student notes of Alexander Davidson. Reproduced with permission from Syndics of the Cambridge University Library.

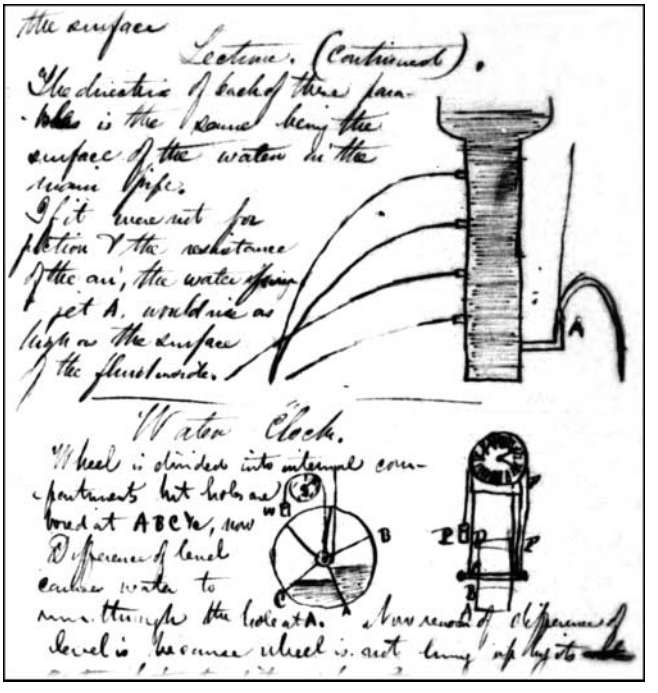

Figure 6. A sketch in Davidson's notes illustrating that Maxwell used some of the prolific store of demonstration apparatus assembled by his predecessors, notably Prof. Patrick Copland. Reproduced with permission from Syndics of the Cambridge University Library.

There is one urban myth about Maxwell which is overdue being discredited—the urban myth that Maxwell was not a good teacher. Maybe it is necessary to distinguish between Maxwell the lecturer to students and Maxwell delivering a lecture to those he took as his peers, in whom he perhaps sometimes assumed too much knowledge or flexibility of mind. This myth may have originated in an

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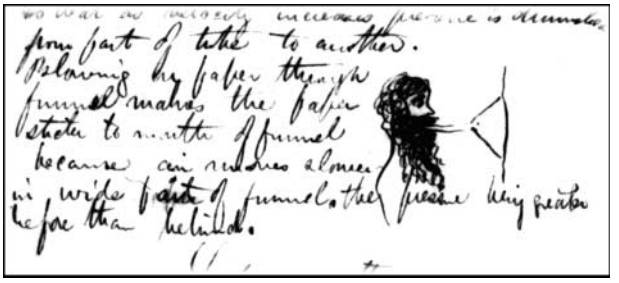

Figure 7. A sketch in Davidson's notes surely showing the professor himself demonstrating the effects of air pressures. Reproduced with permission from Syndics of the Cambridge University Library.

opinion transmitted to the University of Edinburgh when he applied for the professorship there in 1860 that he could only teach able students. The evidence at Aberdeen all points to the fact that Maxwell was an inspiring teacher of students. His attention to student needs and their subsequent positive comments all belie the myth.

In his first year at Aberdeen, Maxwell continued his correspondence with his old school friend P. G. Tait, then professor at the Belfast Institute. A few of his letters have found their way back to Aberdeen and survive in the university archives. Judging by the time Maxwell spent in these letters discussing his teaching, it was clearly high up on his agenda. He seemed pleased with the work put in by his pupils compared with those he had lectured at Cambridge who 'had their time occupied by their coaches and could not work much for a lecture' (Harman 1990*e*). He organized weekly in-class questions, a practice used in the college before Maxwell came and that had also been employed by J. D. Forbes, his old Edinburgh University natural philosophy teacher. He supplemented these by periodic 'formative' examinations on the course content. Both these techniques are approved of today. He had student teas and breakfasts (as some others did in the college), not just for the bright students, for Maxwell commented that 'I am becoming skilful in the conduct of students' teas and breakfasts. I almost prefer to get together a rough lot and set them agoing. I find the uproarious and idle ones best at tea' (Harman 1990*f*).

We have a picture of his breakfasts from a former student. Among more than a hundred books of adventure by Gordon Stables is the title 'From Ploughshare to Pulpit: a tale of the battle of life', published in 1895 (Stables 1895*a*). It is a historical novel about a student who goes to Marischal College, clearly drawing so much on Stable's own experience that there is no attempt to disguise the autobiographical nature of many parts. Indeed, the book is dedicated to the principal of the University of Aberdeen. One-and-a-half pages describe in plain spoken terms the experience of breakfasting with the professors, not fictional characters but, for example, 'Old Dr Brown who filled the Chair of Greek…' (who is sketched in more detail), 'Dr Maclure, Professor of Humanity… a little man, perky, proud and fat… The students called him "Cocky Maclure" but it is to be hoped he did not know this', and so on. He finishes his description with the following: 'Then there was poor Maxwell, so well-known in the scientific world—brown haired, handsome, thoughtful, and wise; he always had some scientific marvel to tell his students during

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breakfast. He was always smiling, but never laughed a deal. I suppose he had an idea that strong tea was not good for young fellows, for he invariably filled the cup half up with rich delicious cream before pouring in the beverage. Poor Maxwell! He is dead and gone, and great loss his death has been to the world' (Stables 1895*b*).

Maxwell went out of his way to make up demonstrations for the students and in fact had access to one of the very best cabinets of equipment in any British university. Indeed, Maxwell not only put on demonstrations but also ran experiments, as he put it, 'being done by the men on their feet and the experiments not cooked in any way' (Harman 1990*f*). This is an exceptionally early documented record of student practical work in a university physics department, though his colleague William Thomson in Glasgow had also initiated student practical work.

He inaugurated a voluntary 'advanced class' for final year students. In his second year, he commented to his aunt Jane Cay 'I have a large attendance of my old pupils… This is not part of the College course, so they come here merely from choice' (Harman 1990*g*). To P. G. Tait 'My regular class is small this year as I expected from the character of the men below, last year. My advanced class (an institution of mine) is large and evidently jealous. With them I expect to do Newton 1, 2, 3 with a sketch of Physical Astronomy, Magnetism and Electricity in the poor weather and Undulatory theory when the Sun appears in Spring' (Harman 1990*f*). His 'ordinary men', as he called them, covered statics, dynamics, hydrostatics, heat and common optics. He related to Tait in a tone of some surprise and pleasure that when his first class returned after the summer break of almost seven months (early April to November), he set them an exam and four men got full marks and only four less than half marks. Try that experiment today and even the best in the lecturing profession would be very pleased with a comparable performance.

Maxwell was not alone in Aberdeen in offering advanced classes and the system was essentially the precursor to the introduction of an honours degree, which did not formally exist in Maxwell's time in Aberdeen, though they had the next best thing. Since Cruickshank introduced the degree exam, after 1828, the best students were declared to have attained their degree 'with honourable distinction'. Formal *honours* appeared in 1860 in the new, merged, University of Aberdeen.[10]

All this evidence is completely consistent with the impression that Maxwell both enjoyed his teaching, put a lot of well-directed thought and effort into it and was appreciated by his students. When he finally came to collect testimonials to support his application for a new job, when Marischal College closed for business as an independent university, he received support over and above the call of duty not only from his fellow professors but also from influential parents of his former pupils. To give one example, Daniel Dewar

[10] The honours degree clearly took time to establish itself. A student at the University of Aberdeen after Maxwell left was the formidably able George Chrystal who studied under Maxwell in Cambridge after taking his Aberdeen degree. He commented 'When I went to the University of Cambridge, I found that the course there for the ordinary degree in Arts was greatly inferior in educational quality to the Scottish one. On the other hand, the courses in honours were on a very much higher standard.' G. Chrystal, Promoter's address to graduates of arts, University of Edinburgh, *The Scotsman*, Edinburgh, 11 April 1908.

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commented in his testimonial that there was only one class in Marischal College which was larger than the corresponding one in King's College and that was Maxwell's natural philosophy class. This in spite of the King's professor's substantial reputation. There is more to say on Prof. Thomson later, for he contributed to Maxwell leaving Aberdeen.

Maxwell a poor teacher? Unfortunately, everyone connected with universities has met their share of poor teachers. Maxwell does not compare with them. Physics departments would be a bigger inspiration to students across the country if we had more like him.

5. Maxwell's evening class

In October 1857, Maxwell undertook to give the natural philosophy course of the 'Aberdeen School of Science'. This course of 20 lectures ran for one evening per week (Monday, at 8 o'clock in the evening) for exactly the same span as the college classes, namely five months from early November until early April.[11] The fee was 8 shillings per student; most, if not all, of this would have gone to the lecturer. The Aberdeen School of Science, which was already established when Maxwell arrived, was advertised as having 'the special object of affording to young Mechanics, Tradesmen, &c., instruction in those branches of Science which are of the greatest practical utility in the chief trades, arts, or professions, followed in this locality; and also to afford instruction in Practical Science to others that may be prevented by their means or avocations from attending on such Classes during the day … The School is open to Ladies; and the attention of Teachers and Pupil Teachers is particularly invited'. Students of the school were given access to the library of the Aberdeen Mechanics' Institution, under whose auspices the school flourished,[12] and could expect the lectures in natural philosophy and chemistry to be illustrated by Marischal College apparatus, by courtesy of the College Senate. The natural philosophy course had been started by Prof. Gray of Marischal College at the opening of the school in 1854.

At the end of the course, students could present themselves for an exam, overseen by the Department of Science and Art in London. For example, only four did in natural philosophy in 1858: a draughtsman; a watchmaker; a blacksmith; and a clerk, obtaining marks ranging from 75 to 25%. In the following year, the prize list of three included a watchmaker and a student but by implication there were non-prizemen too. I suspect that the number of students taught by Maxwell was modest. Over the 3 years preceding Maxwell's teaching at the school, numbers in natural philosophy had fallen from 42 to 14.

[11] Relevant advertisements for the 'Aberdeen School of Science' appear in *The Aberdeen Journal*, 21 October 1857, 28 April 1858, 20 October 1858, 27 April 1859, 19 October 1859. The April advertisements detail the prizemen and women.

[12] The link with the Aberdeen Mechanics' Institution, is discussed by Fraser G. M. 1912 *Aberdeen Mechanics' Institute*, ch. X, Aberdeen University Press. See also *Aberdeen Mechanics Institution Minute Book No. 3* in Aberdeen Public Library Lo370.6 Ab 3.4 for the details of the running and examinations of the School of Science and Art from 1856 to 1859. Further details are in *Minutes of the School of Science & Art Aberdeen Book no. 9* in Aberdeen Public Library Lo 370.6 Ab3.4 52215.

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Maxwell inherited a course that had embraced statics, mechanics, hydrostatics, hydraulics, pneumatics, acoustics, optics, heat and the steam engine, and the electric telegraph, taught in about 30 lectures. This seems a tall order. Maxwell's shorter course of 20 lectures would have had a reduced scope. In one letter of 1857 to C. J. Monro, Maxwell wrote that he had 'also a class of operatives on Monday evening who do better exercises than the University men about false balances, Quantity of Work etc.' (Harman 1990*h*).

Such lectures to tradesmen were not an innovation in Aberdeen; indeed, the city had led developments in London and elsewhere in England by many years. A predecessor in Maxwell's chair, the same Prof. Copland who built up such a tremendous stock of demonstration equipment, had given a much longer public course on natural philosophy over a period of almost 30 years from the mid-1780s (Reid 1987). Copland's successor at Marischal College, Prof. Knight, was the founding lecturer in natural philosophy at the Aberdeen Mechanics' Institution. In 1824 and in the subsequent years of euphoria for such institutions, he lectured to audiences of several hundred. Nonetheless, Maxwell, like his predecessors, undertook this work out of his own interest and motivation. Maxwell had begun lecturing to tradesmen in Cambridge and indeed continued this interest when he took up his post at King's College London. Whether it seemed odd in mid-Victorian society for the laird of Glenlair to be lecturing working men is not recorded, but Maxwell's interest was both genuine and did not imply any lack of commitment to his inherited role as owner and manager of a minor estate, a role he also felt comfortable with.

When Maxwell left, no one immediately stepped in to continue the natural philosophy course at the Aberdeen School of Science.

6. Maxwell's research

Maxwell wrote eight papers while at Marischal College, spanning 150 published pages (Niven 1890). Producing 150 published pages of cutting-edge physics while simultaneously preparing and delivering 15 hours of lectures a week for five months, a voluntary advanced class for several further hours per week, undertaking practical work with students, entertaining them, participating in college life, keeping up an extensive correspondence with friends, colleagues and relatives, reading widely and volunteering to give evening classes is a truly impressive productivity that would be the envy of any physics professor in Britain today.

Maxwell's research at Aberdeen has been covered in detail elsewhere (Everitt 1974; Tolstoy 1981; Goldman 1983) and is also addressed in accompanying papers in this issue. In brief, Maxwell spent some time developing his famous dynamical top and a very large amount of time developing his Adams Prize treatise on the stability of Saturn's rings (Brush *et al.* 1983). His most underrated activity was the work he did to establish the foundations of modern colour theory, establishing the mathematical representation of colour mixing, devising the Maxwell colour triangle (from which the modern CIE chromaticity diagram has developed) and devising a particularly effective apparatus for determining the colour coefficients of pure spectral wavelengths. Out of this came the first quantitative measurement of a colour defective, a pupil James Simpson in his

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class, and the three-colour separation method of making photographic colour pictures. On the subject of optics he set out the general theory of perfect optical imaging that allows the layout of optical instruments to be designed simply by knowing the location of the cardinal points of their optical components. Finally, in a paper of ground-breaking originality, he laid the foundations of the kinetic theory of gases, one of the main achievements of his life (Garber *et al.* 1986). The depth, the breadth and the originality of Maxwell's work is well sampled by his activities while he was at Marischal College.

7. Maxwell's denouement

That Maxwell lost his job at Aberdeen is legendary. Another urban myth that refuses to die is that the University of Aberdeen sacked him. It has always seemed to me very unlikely that Maxwell was made redundant by the university, for the following simple reason. The Scottish universities were, and some might say have been until quite recently, patriarchal institutions. It is inconceivable that one could marry the principal's daughter, be welcomed into the principal's family, and then be made redundant. That would not happen to anyone verging on the incompetent, never mind Maxwell. What happened?

Maxwell began the 1859 academic year in November as usual. He also undertook for the third year in succession the natural philosophy classes of the Aberdeen School of Science. It must have been pretty clear in late 1859 that only one professor of natural philosophy would survive the imminent merger of the two universities. This was in fact the crux of the difference between *fusion* and *union*. Maxwell was a self-confessed fusionist. Fusion meant a surviving arts faculty after the amalgamation with one professor in each subject; union implied retaining two professors in each subject.

Scarcely a week into the term, Maxwell heard that J. D. Forbes was resigning from his chair of natural philosophy at Edinburgh to become principal at St Andrews. Earlier that year, the chair of natural philosophy at St Andrews had been vacant. Maxwell had done nothing about it and William Swan was appointed. He now surmised that the Edinburgh chair would soon become vacant, and immediately set about increasing his stock of testimonials from influential friends: he saw it as 'promotion in any case'. David Thomson, professor of natural philosophy at King's College, also declared his potential candidacy, as did Frederick Fuller of King's. Aberdeen's professors clearly feared they were on a ship heading for the rocks. Maxwell obtained separate testimonials from almost all the staff at Marischal College, including Cruickshank, Brown, Clark, Martin, Maclure; the notable Professors Ogston and Macrobin from the Medical School, Principal Dewar himself, the dean of faculty (Sir Thomas Blackie) and John Webster, who had been Lord Provost of Aberdeen from 1856 to 1859, ex-rector's assessor to the college and whose own son had been taught by Maxwell. This was the response of a college that thought extremely highly of Maxwell. Most of the college references refer to Maxwell's zeal at teaching, his success at 'communicating to every intelligent mind among his students a clear knowledge of the subject and inspiring not a few of them with a decided taste for the cultivation of physical science in after life' (as Macrobin worded his praise). Macrobin's son had attended Maxwell's

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class, as had the son of John Brown, professor of botany at King's College and the Reverend James Smith, all of whom wrote testimonials.

On 10 January 1860, the royal commissioners published their ordinances for fusing the two universities into one, among which was written 'The two Professorships of Natural Philosophy in the said existing Colleges shall be conjoined, and shall be the Professorship of Natural Philosophy in the University of Aberdeen, which shall be held by David Thomson, Master of Arts, now Professor of Natural Philosophy in King's College'. 'I am to be turned out by the Commissioners' Maxwell wrote to a friend two weeks later (Harman 1990*i*). His chair was a Crown appointment; what the Crown was pleased to grant, it could also withdraw. It is ironic that one of the express purposes of the fusion of the two colleges was that 'by uniting classes and salaries, a respectable maintenance would be secured for the masters, and consequently the means of obtaining the best masters' (quoted by Simpson 1963). Although to scientific posterity the act of letting Maxwell go was a gross mistake, not one of the commissioners was a scientist.

Who was this Thomson who had taken precedence over Maxwell? He was a graduate of Glasgow and Cambridge who had returned to Glasgow in his early 20s to act as a professor substitute for the ill Prof. Meikleheim (Low 1894). By all accounts, Thomson was very effective. The future Lord Kelvin was among his pupils, succeeding in a few years to Meikleheim's chair in 1846. With 5 years' experience under his belt, David Thomson arrived at King's College in 1845 like Maxwell 11 years later, a young man still in his 20s set down among elderly staff. There the resemblance fades. Thomson quickly entered into the running, and indeed the modernization, of King's. As one commentator put it 'He was the strong man in [King's] Senatus from first to last. When he was in his prime, no dog barked' (Leask 1917). He quickly rose to become secretary and sub-principal at King's College, an effective administrator, an effective teacher who even by 1860 had another 20 years of professorial life ahead of him. As a political operator, he was known with good reason as 'crafty Thomson'. Thomson and the lord rector of King's College, John Inglis, one of Scotland's senior lawyers, are widely recognized as the significant influence behind the commission's decisions.

Maxwell was not without influential friends and family connections but he had been a novice of one year's standing when the commissioners had come to Aberdeen in 1857; a young man who had spoken in low key to the commission, in marked contrast to the wide-ranging evidence submitted by Thomson. The commissioners may or may not have noted that Maxwell was not much interested in university administration (witness his record on the Senate) and that he retreated to his estate for six months in the year. Maxwell may indeed have held the ace of trumps, but unfortunately no one told the commissioners what suit were trumps. The commissioners came in for a substantial amount of very public criticism during 1859–1860 from politically active nobility and supporters of Marischal College. They roundly abused the commissioners on many counts for making rash and unwise decisions and taking uncalled for action that was injurious to the cause of education in the north of Scotland.

There are several curious circumstances associated with the whole episode of Maxwell's departure. First, the commissioners apparently sought no official evidence at all on the fitness of any of the professors for their posts. Any decision

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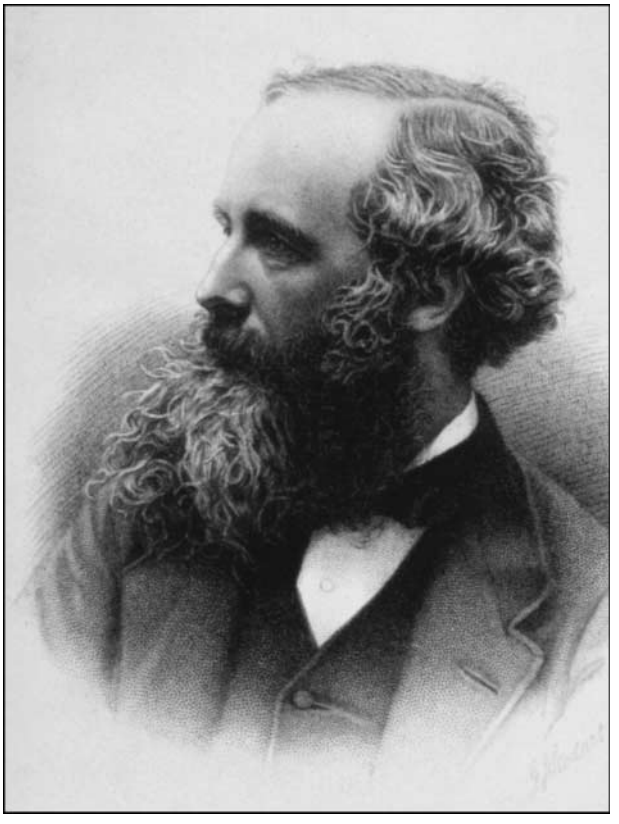

Figure 8. James Clerk Maxwell as his biographers Campbell and Garnett wished him to be remembered.

would therefore not have been based on a careful weighing of all relevant facts. Second, the commissioners declared without any explanation that the chair of natural philosophy was henceforth to be under the patronage of the university, the only Crown appointment to lose its status. Third, they also declared that super-annuated professors would be reimbursed under the rules of the Superannuation Act for the Civil Service, one of which was that 'no retiring allowance should be granted before a period of service of ten years' excepting in cases of peculiar hardship to be adjudicated by the Lords of the Treasury. One university historian (Bulloch 1895) asserts that as compensation to those compulsorily retired, their full salaries were paid during their lifetimes. This may have happened to the long-established professors but there is some doubt that Maxwell received any compensation.

If the commissioners could have argued with posterity, they might well have retorted that if Maxwell was as good as was claimed, he should easily be able to get another chair. In the event, Maxwell did not get J. D. Forbes' position at Edinburgh but was appointed to King's College, London, almost exactly six months after the commissioners' ordinances were published and before his tenure at Marischal College had officially expired.

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8. Concluding remarks

Maxwell's reputation[13] is, of course, built upon more than his Aberdeen work which spans, as I said at the beginning, only some quarter of his professorial career. There are few visible reminders in Aberdeen that Maxwell spent four formative years here.[14] Next time you park in Marischal quad, still recognizably the place shown in figure 1, remember that 150 years ago shortly before 9 o'clock on any winter's morning you might well have seen James Clerk Maxwell (a little younger than shown in figure 8) walking to his rooms 'a man of middling height, with frame strongly knit, and a certain spring and elasticity in his gait; dressed for comfortable ease rather than elegance; a face expressive at once of sagacity and good humour, but overlaid with a deep shade of thoughtfulness; features boldly but pleasingly marked; eyes dark and glowing; hair and beard perfectly black, and forming a strong contrast to the pallor of his complexion'—not Gordon Stables this time but quoted by Walker (1916) and to be found in Campbell & Garnett (1882).

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[13] By the beginning of the twentieth century, Maxwell was cited as one of the outstanding academics in the 400-year history of the University of Aberdeen. P. J. Anderson (ed.) *Record of the Celebration of the Quatercentenary of the University of Aberdeen*, Appendix G 'Addresses presented by Universities and Learned Societies'. The Royal Society's tribute under the name of the President Lord Rayleigh singles out Maxwell with the words 'within living memory the UNIVERSITY has numbered among its professors the world-renowned path-finder JAMES CLERK MAXWELL'. The Royal Academy of Sciences in Amsterdam is even more explicit 'In Vestra Urbe Maxwellus ille Faradayanum cogitatum "spinam dorsalem" fieri posse intellexit novae rationis electrodynamicae, quae doctrinas de lumine et electricitate in unum coniunctura erat opus splendidum magnificumque, quaeque immortalem ipse Maxwello gloriam afferens postea nastis Viris doctis viam munitura erat, qua in novam quondam possent penetrare naturae regionem, de qua ante hac ne suspicati quidem quidquam errant hominess'. Other tributes from Cambridge, the University of Leyden and the British Academy all mention Maxwell.

[14] A posthumous bust by the Edinburgh artist Charles D'Orville Pilkington Jackson, created for the centenary of his appointment to Marischal College and displayed on the wall of the Marischal College Picture Gallery; a plaque outside his former lodgings in 129 Union Street, also erected in 1956; a suburban street named after him, Clerk Maxwell Crescent.

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